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INFORMATION CIRCULAR

MINING AND MILLING OPERATIONS OF THE SOUTHWESTERN GRAPHITE CO., BURNET COUNTY, TEX.

BY

A. B. NEEDHAM

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MINING AND MILLING OPERATIONS OF THE SOUTHWESTERN GRAPHITE CO., BURNET COUNTY, TEX.[1]

By A. B. Needham[2]

INTRODUCTION

Graphite is a raw material of considerable importance in both war and peace. Two types of graphite, classified according to particle size as flake and fines, are used, but the former is in much greater demand. The principal wartime use of graphite is in the manufacture of crucibles for melting brass and special alloys of copper and steel. Other uses in both peace and war are as lubricants, for foundry facings, and in paints, electrodes, batteries, motor and generator brushes, and a variety of other commodities.

This paper describes the operations of the Southwestern Graphite Co. of Los Angeles, Calif., which produces both flake and fine graphite from a property in Burnet County, Tex.

ACKNOWLEDGMENTS

Acknowledgment is made to the executives of the Southwestern Graphite Co. for permission to publish this paper and especially to L. C. Penhoel, superintendent, W. H. Smith, bookkeeper, and W. H. Dodson, chemist, for their willing and valuable assistance in its preparation.

LOCATION

The mill and nearby mine are in the west-central part of the county, 11 miles northwest of the town of Burnet. The route to the property is 3-1/2 miles west on Highway 29 and the remaining 7-1/2 miles northwest on a dirt road. The Texas & New Orleans railroad, a branch of the Southern Pacific from Austin through Burnet, connects with the Atchison, Topeka & Santa Fe at Lampasas, which is 20 miles to the north. The property consists of 41.6 acres of the E. H. Jobe Survey No. 500 and 15.73 acres of the D. C. Golden Survey No. 1,252 in Burnet County, Tex.; it is a narrow strip of land extending along the strike of the outcrop for a distance of 1 mile.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular No. 7339."

[2] Mining engineer, Bureau of Mines, Austin, Tex.

HISTORY

The deposit was first worked in 1913 by P. B. McCabe of Denver, Colo. In 1917 the Southwestern Consolidated Graphite Co. began mining the property and continued until 1930, when the company ceased production. In May 1935 the present owners purchased the property.

The original mill was operated by the Southwestern Consolidated Graphite Co. from 1922 until it burned in 1927. The mill was rebuilt at once to treat 500 tons of ore a day and operated until 1929. The production of concentrate during this period was 9,385 tons. The electrifying of radio sets by alternating current nearly extinguished the industry of manufacturing dry batteries for radio work and with it the demand for battery-grade graphite, the principal product of this mine, causing cessation operations. In 1942, after the present operators had owned the property for several years, a loan was obtained from the Defense Plant Corporation, and the mill was reconditioned. On September 1, 1942, the mill began operation on a schedule of five 3-shift days a week. In 1943, 49,066 tons of ore were treated to recover 2,660 tons of graphite concentrate. During the first 10 months of 1944 the plant operated one shift a day, 6 days a week, but since November 1944 the operating time has been increased to two shifts a day, 6 days a week. Production for 1944 was 1,231 tons of graphite concentrate from 21,376 tons of ore. The company is currently treating 4,000 tons of ore monthly to produce 200 tons of concentrates.

GEOLOGY AND ORE DEPOSITS

The deposits are in the Packsaddle schist of the Central mineral region. The graphite is found as a stratum of graphite schist which trends northeast-southwest and dips 80° north. The deposit has been prospected for 6,000 feet, although exploratory work has been done over only 1,400 feet. The ore body being mined strikes N. 65° E. It is elliptical, is approximately 1,400 feet long by 150 feet in width at the widest point, and tapers to 50 feet in width at each end. The downward extent is unknown. The deposit is cut by occasional narrow gneiss dikes. The walls are hornblende schist. The minerals are chiefly quartz, graphite, hornblende, and small amounts of pyrite and mica. The average grade is 5.5 percent carbon. Two other ore bodies are present on the same property, one northeast and the other west of the ore body being mined.

EXPLORATION

Exploratory test holes drilled before 1930 indicated approximately 2-1/2 million tons of ore, which is sufficient to assure operation for many years. Test holes drilled to a depth of only 50 feet on the west ore body have disclosed 415,000 tons of ore with an estimated grade of 4.8 percent carbon. Holes drilled to a depth of 110 feet on the middle ore body have proved 1,000,000 tons with a grade of 5.5 percent carbon, and the northeast deposit is estimated to contain 1,000,000 tons, based on scattered prospect holes to a depth of 50 feet below creek level. All ore bodies apparently are mineralized to a much greater depth than has been explored, and it is believed

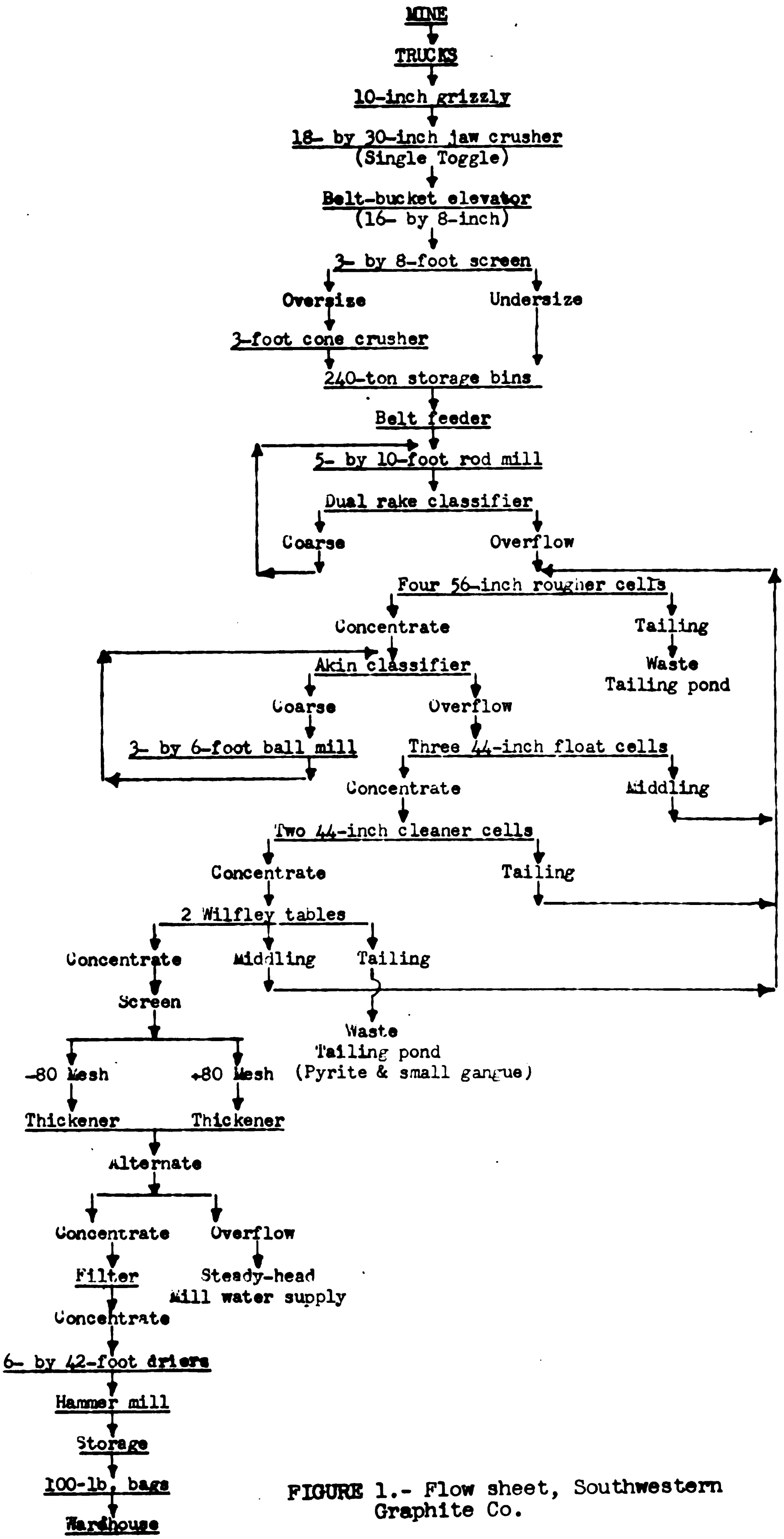

FIGURE 1.- Flow sheet, Southwestern Graphite Co.

that adequate reserves are assured for a long period of operation. The company is prepared to extend the reserves by deeper drilling when necessary.

MINING

The ore currently mined by the company is from the middle ore deposit. The overburden is approximately 15 feet thick and is removed before mining by the open-pit method. Ore is mined from a single bench, at right angles to the strike. The face is carried 16 feet high for the full width of the quarry and advanced from west to east.

For breaking the graphite schist, vertical blast holes are drilled 4 feet apart in a single row to a depth of 18 feet by Sullivan wagon drills, using 1-1/4-inch lug steel and side-hole jack bits. The holes are loaded with Atlas 60-percent gelatin dynamite, and the charges are detonated, 30 to 35 at a time, by electric detonators. A 16-foot bench is broken. The amount of ore broken per pound of powder ranges from 2.7 to 3.0 tons.

Secondary drilling of the large pieces of ore is done with Sullivan jackhammers, using 1-inch hexagon steel and side-hole jack bits. Atlas No. 3 Gelodyne is used to break the large boulders. The over-all powder consumption is 0.53 pound a ton of ore. Average footage for a jackbit is 4.3 feet.

The ore is loaded with a P. & H. gasoline-driven shovel with 3/4-yard bucket, mounted on caterpillar treads. It is hauled from the quarry floor to the plant, an average distance of 1/2 mile, in two Dodge trucks. The nominal capacities of these are 1-1/2 tons and 2 tons, but the actual load is 5 tons.

Quarry operations, which employ 11 men including a foreman, are on a one-shift basis, and an average of 175 tons of ore daily with a grade of 5.5 percent carbon is produced.

Particular attention is paid to the maintenance of safe working conditions by carefully scaling the banks of the pit and keeping them free of loose rock. The lost-time accident record is remarkably low, with only one lost-time accident recorded for the past year of operation.

MILLING

The treatment of the material consists of crushing and grinding to free the graphite, concentration and cleaning by flotation, final cleaning by tables, screening, filtering, and drying.

The present flow sheet, which is shown in figure 1, was adopted in January 1944, after an experience of 2 years. It has resulted in increase of capacity from 9 tons an hour to 10 tons, an increase of 2 percent in the grade of the concentrate, and a decrease of 0.2 percent in the loss of carbon in the tailing. The capacity of the plant is 240 tons in 24 hours. It is operated two shifts a day.

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At the plant the ore is discharged from trucks onto a horizontal-rail grizzly with 10-inch spacing, and the oversize is sledged through into a small surge bin of 10-ton capacity. A hand-operated gate controls the flow of ore from the surge bin into a Telsmith single-toggle jaw crusher, driven by V-belts from a 60-hp. General Electric motor, and set for 3-1/2-inch discharge. The crushed ore is conveyed by a belt-bucket conveyor to a 3- by 8-foot Allis-Chalmers 1-deck primary screen with 3/4-inch openings. Secondary crushing is done by a 3-foot Symons short-head coarse-bowl cone crusher, powered through V-belts from a 60-hp. motor and with a countershaft speed of 580 r.p.m. Stephens-Adamson conveyors are used to take the ore to the mill bins. No reliable estimate is available of the proportion of ore actually broken in the primary crusher. The nature of the ore and the methods used in open-pit mining tend to yield a product of unpredictable character. Possibly 40 percent of the ore actually is broken by the jaw crusher. Two men operate the crushing section on one shift a day. The head crusherman reports daily the number of hours operated, time lost and cause, and the number of truckloads delivered.

Primary grinding is by a 5- by 10-foot Mine & Smelter Supply Co. Marcy rod mill, driven by V-belts from a 100-hp. motor and run at 21 r.p.m. Secondary grinding of the rougher concentrate from the first flotation cells is done in a 3- by 6-foot ball mill run at 28 r.p.m. Manganese-steel breast liners, side liners, and grates are used. Forged-steel balls are used, and a relatively light ball load is maintained, averaging 2,600 pounds.

The reground rougher flotation concentrate is given one to three cleanings, dependent on the grade of combined concentrate desired. The rougher consists of four American Cyanamid Co. Fagergren 56-inch cells, each driven by a 7-1/2-hp. motor. The cleaner machines are a set of three 44-inch cells, followed by two 44-inch cells. Each of the cleaner cells is driven by a 5-hp. motor. The flotation reagents are pine oil, sodium silicate, and kerosine. American Cyanamid Reagent No. 633 also is used as a depressant.

The pine oil and sodium silicate are introduced into the overflow of the classifier at the rate of 0.1 and 0.3 pound per ton of ore, respectively. Only an occasional trace of kerosine is used. The depressant is fed before the final concentration at the rate of 0.02 pound to a ton of ore.

Final cleaning is by two Mine & Smelter Supply Co. Wilfley tables, which remove most of the pyrite and free gangue minerals remaining in the final flotation concentrates, after which a wet separation of fines and flake is made by rotary screens ahead of the respective thickeners. The screens are hexagonal trommels 19 inches in diameter by 8 feet long. The screen is bronze wire with 0.0070-inch openings. A screen analysis of the material from the screens follows:

Plus	50-mesh	8 percent
Plus	70-mesh	34 percent
Plus	80-mesh	21 percent
Plus	100-mesh	26 percent
Plus	200-mesh	9 percent
Minus	200-mesh	2 percent

The thickeners are Dorrco rake-type, 30 feet in diameter, 10 feet high and having a capacity of 12 tons. Sixty square feet of thickener area is required to settle 1 ton of flake.

The concentrate from either thickener flows by gravity to a Dorrco filter. The filter cake is dried on two 7- by 40-foot Lowden pan-type driers, fired by fuel oil and with the heat circulated through openings and around baffles.

Conveyors carry the graphite to storage bins from which it is loaded into 5-ply paper bags, each holding 100 pounds. Composite samples are made of each 20 sacks, and the various grades are segregated and stored in a warehouse.

Two classes of concentrates, called Grade A and Grade C, are recovered. Grade A, which is plus 80-mesh, is called flake and must contain more than 85 percent carbon. Grade C, which is minus 80-mesh, is called Texas fines and ranges in grade from 75 to 95 percent carbon. A wide variation in the grade of combined concentrate is permissible so long as it does not fall below 75 percent carbon, but the grade of flake size must be 85 percent carbon or better, otherwise there is no market for the product. Therefore every effort is made to obtain the highest grade of flake size regardless of the grade of combined concentrate. The grade of flake size is not entirely conditional on the grade of the fines. Flake containing more than 90 percent carbon can be produced, even though the grade of the fines is in the lower range of plus 75 percent carbon. Currently the grade of flake-size concentrate averages 94.4 percent carbon and that of the combined concentrate about 92.0 percent. Because of increasing demand for high carbon content of both flake and fines, efforts are being made to maintain the high grade of the products. The management expects to change the present method of dewatering and drying the concentrates to accomplish this. Twelve men, including one sacker and one tailing-pond tender, are employed in the mill. The monthly production is 200 tons of combined concentrate from 4,000 tons of ore treated.

The sacked concentrates are trucked under contract 11 miles to Burnet in 6-ton loads. Sales are made exclusively through the Eastern Graphite Sales Co., Asbury Park, N. J.

POWER AND WATER

The Colorado River and its tributaries drain the western part of Burnet County, and the Buchanan Dam of the Lower Colorado Authority is located on the river about 3 miles west of the mill. The power is transmitted from the Buchanan Dam to a substation at Burnet at 69,000 volts. The current is delivered to the plant at 12,500 volts and is reduced to 440 volts for general use. Approximately 110,000 kw.-h. are used to treat 4,000 tons of ore. This includes mining, milling, pumping, lights, and miscellaneous uses. The total power consumption for all purposes averages 26 kw.-h. a ton of ore.

Water is obtained from Clear Creek, which flows through the property and empties into Inks Lake. During a short dry season water is pumped from Inks Lake through a 5-inch line 2.1 miles long. The concentrator and general works

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use 175 gallons of water a minute, of which 100 gallons a minute is return water from the overflow at the thickeners. A varying quantity of water is also reclaimed from the tailing pond.

FLOTATION DATA

In November 1944, when the plant was placed on a 2-shift basis, the operation was in the experimental stage, and the results have been gradually improved. By February 1945 the following results were obtained:

Heads, percent carbon	5.10
Tailing, percent carbon	.40
Combined concentrate, percent carbon	92.50
Flake concentrate, percent carbon	93.90
Recovery of carbon, percent	92.50
Ratio of concentration	19.6 : 1
Tonnage treated, hourly	10.3

LABOR

	Number	Wage scale hourly rate
Mining (1-shift basis)		
Drillers, primary wagon drills	2	$0.75
Drillers, secondary J. H. drills	2	.65
Powderman	1	.80
Shovel operator	1	1.25
Shovel helper	1	.80
Truck drivers	2	.75
Bit grinder	1	.65
Foreman	1	1.25
Total	11	
Milling		
Crushermen (1-shift basis)	2	.0775
Mill operators (2-shift basis)	4	.75
Driers (3-shift basis)	3	.75
Drier helper	1	.65
Sacker	1	.675
Tailing-pond man	1	.75
Total	12	
General		
Superintendent	1	
Chemist	1	
Master mechanic	1	
Mechanic and plant foreman	1	
Electrician	1	
Office	1	
Pumpman	1	
Bus operator	1	
Total	8	
Grand total	31	

CONNECTED POWER

	Horsepower
Quarry	5
Crusher	60
Belt-bucket conveyor	10
1-deck screen	2
Cone crusher	60
Belt conveyor	30
Feeder belt	3
Rod mill	100
Rake classifier	3
56-inch rougher cells	30
Wilfley pump	80
44-inch cleaner cells	15
Akin classifier	1-1/2
44-inch cleaner cells	10
Tables	3
Screen	5
Thickeners	5
Drier	10
Filter	5
Hammer mill	5
Conveyor (sacking room)	10
Vacuum pump for filters	20
Blower	6
Air compressor	60
Water main	10
Power saws	10
Grinder	10
Lathe	3
Total connected power	571-1/2

Power Costs

First 300 kilowatts, demand charge	$1.40/Kw.
Excess kilowatts, demand charge	1.20/Kw.
First 10,000 kilowatt hours	.01/Kw.-h.
Next 40,000 kilowatt hours	.008/Kw.-h.
Excess kilowatt hours	.006/Kw.-h.

In addition a developmental charge of 10 percent of the overall bill is imposed

COST OF MAJOR SUPPLIES

Grinding balls	$ 3.39 a 100 lb.
Mill liners	.132 a lb.
Sacks (5-ply paper)	.135 each
Fuel oil	.06 a gallon
Gasoline	.10 a gallon
Dynamite, 60 percent and No. 3 Gel.	14.25 a 100 lb.
Fuse	6.20 a 1,000 ft.
Caps	15.40 a 1,000 ft.
Electric detonators, 8' length	8.30 a 100
Electric detonators, 20' length	11.30 a 100
Pine oil	.625 a gallon
Jack bits	.32 to 0.45 each
Sodium silicate	.621 a lb.
American Cyanamid No. 633	.118 a gallon
Kerosine	.07 a gallon

COSTS

The following is a summary of costs for a representative period:

Direct Operating

Mine	Dollars a ton of ore mined		
Labor			
Wagon drilling	$0.098		
Secondary drilling	.069		
Shoveling	.113		
Trucking	.071		
Powderman	.050		
Foreman	.069		
Maintenance	.116		
Supervision and office	.093	$0.679	
Supplies			
Explosives	$0.021		
Fuse and caps	.025		
Jack bits	.046		
Gasoline	.022		
Oil and Grease	.006	.120	$0.799

Mill	Dollars a ton of ore milled	
Labor		
Crushing	0.078	
Concentrating	.181	
Drying	[1] .172	
Sacking	.038	
Tailing Pond	.038	
Maintenance	.163	
Supervision and office	.104	0.774

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[1] Cost of labor per ton of concentrate dried, $4.15.

Direct Operating (Continued)

	Dollars a ton of ore milled		
Mill (Continued)			
Supplies			
Reagents	$0.017		
Grinding rods	.036		
Oil and grease	.001		
Fuel oil (dryers)	[2].115		
Power	.380	$0.549	$1.323

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[2] Cost of fuel oil per ton of concentrate dried, $2.76.

Indirect Operating

	Dollars a ton of ore milled	
Insurance	$0.054	
Taxes	[1].059	
Miscellaneous	[2].005	
Main office	.070	
Salaries to officers, commissions and discounts	.843	$1.031

SUMMARY OF MINING AND MILLING COSTS

	Dollars a ton of ore milled	
Direct		
Mining		
Labor	$0.679	
Supplies	.120	$0.799
Milling		
Labor	.774	
Supplies	.549	1.323
Indirect	1.031	1.031
Grand total mining and milling	3.153 per ton	

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[1] Includes social security, excise, state unemployment, auto, franchise, and real estate taxes.

[2] Includes bank exchange and service and rent on furniture.

Direct Operating (Continued)

Mill (Continued)	Dollars a ton of ore milled		
Supplies			
Reagents	$0.017		
Grinding rods	.036		
Oil and grease	.001		
Fuel oil (dryers)	2/ .115		
Power	.380	$0.549	$1.323

2/ Cost of fuel oil per ton of concentrate dried, $2.76.

Indirect Operating

	Dollars a ton of ore milled	
Insurance	$0.054	
Taxes	1/ .059	
Miscellaneous	2/ .005	
Main office	.070	
Salaries to officers, commissions and discounts	.843	$1.031

SUMMARY OF MINING AND MILLING COSTS

Direct	Dollars a ton of ore milled	
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Indirect	1.031	1.031
Grand total mining and milling		3.153 per ton

1/ Includes social security, excise, state unemployment, auto, franchise, and real estate taxes.

2/ Includes bank exchange and service and rent on furniture.